Effect of Physical and Mineralogical Properties of Aggregates on Quality of Asphalt Concrete

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Abstract : The major component of an asphalt matrix is rock aggregates usually consisting an amount greater than 95% by weight. One of the main reasons causing failure of asphalt paved roads during the expected service period of the pavement, is due to the shortage of the quality of aggregates being used. In the local asphalt industry, aggregates used to produce asphalt concrete, are tested and approved for the application only by evaluating physical parameters such as LAAV and AIV. In this research, mineralogical properties of aggregates have been systematically analysed along with the respective physical and asphalt properties. Testing was carried out for aggregate and lump samples collected from a number of metal quarries and asphalt plants, representing rock types from three major geological complexes; Wanni, Highland and Vijayan of Sri Lanka. Both single and multiple statistical linear regression analytical tools were adopted to analyse the relationship between mineralogical properties with physical and asphalt properties. Findings of the research proposes to consider the collective influence of both physical and mineralogical properties of aggregates when selecting competent materials for asphalt concrete manufacture.

Keywords: Aggregate Physical Properties, Aggregate Chemical Compositions, Asphalt Concrete

1. Introduction

The highway and road network developments are identified as the current major infrastructure development projects in Sri Lanka. According to national road statistics provided by Sri Lankan Road Development Authority, the total length of national highways in the country is approximately 12,379 km by the end of year 2015. Almost all of these roads are paved using asphalt concrete.

Sri Lanka is also the country with the highest road network density among South East Asian countries [1]. Hence, durability and long term performance of roads are the dominant requirements to be achieved by the construction industry.

Primarily, asphalt concrete is a mix of bitumen and a blend of densely graded aggregates. Mix proportions of the asphalt concrete are determined after a process of mix design to achieve the desired strength and durability against expected traffic and adverse climatic conditions by using available aggregates[2].

The quality of asphalt concrete plays a major role in this context. Thus, the influence of the quality of aggregates which is the major component of an asphalt matrix is very much important to be addressed in order to optimize the quality of ultimate asphalt concrete mixtures and the durability of asphalt pavements[3].

The main objective of this research is to assess the effect of physical and mineralogical properties of rock aggregates on the quality of asphalt concrete.

This study involves the collection of a number of representative aggregate samples which are currently being used in the process of manufacturing asphalt in certain parts of Sri Lanka. The study area has been illustrated in Figure 1. A series of tests have been carried out to determine both the physical and mineralogical properties of aggregates and quality of asphalt in this study. The test results were used to carry out performance analysis by means of statistical linear regression analytical tools.

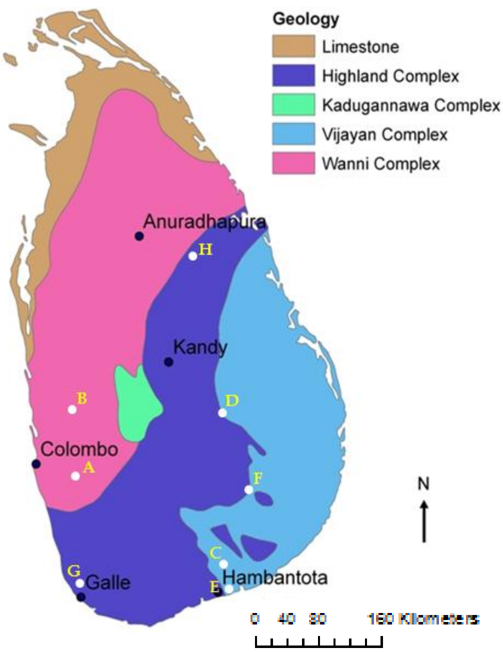

Figure 1: Distribution of sampling locations

2. Material and Methods

The research methodology consists mainly of a preliminary data analysis, field data gathering and analysis, sample collection, testing, analysis of test results followed by drawing of conclusions and recommendations.

2.1 Preliminry data analysis

Prior to start with the field visits, sample collection and testing, preliminary data gathering and analysis were conducted.

Gathered data included information relating to the basic structure of a typical road cross section, different types of courses available (base course, sub base course, surface course etc.), functions of each course, characteristics of the materials used in each of these layers, standard tests available, national road statistics and types of rocks used to produce aggregates in the local asphalt industry.

2.2 Field data analysis

First field visit was on 11/09/2015 to the Asphalt Plant & Laboratory, Kotadeniyawa owned by Access Engineering (Pvt) Ltd., in order to gather more information on manufacturing process of asphalt concrete, and quality control tests conducted to ensure the quality of asphalt production.

2.3 Sample collection

Samples were collected from eight different locations, representing different rock types available in largest three geological complexes in the country. The details of the sampling locations are given in Table 1.

Table 1: Details of sampling locations

Sampling Location ID / Rock Type	GPS Coordinates	
	Easting	Northing
A / Hornblende Biotite	6.859993°	80.099631°
B / Charnockite	7.283568°	80.088620°
C/ Biotite Gneiss	6.3161033°	81.0543646°
D / Charnockitic Gneiss	7.2578207°	81.045000°
E / Biotite Gneiss	6.151947°	81.111282°
F / Biotite Gneiss	6.7792709°	81.2224412°
G / Charnockite granulite with garnet	6.212535°	80.136023°
H / Charnockitic gneiss	8.245395°	80.875168°

2.4 Laboratory Testing

2.4.1 Physical properties

Bulk Specific Gravity, Uniaxial Compressive Strength (ASTM D7012 – 14), AIV (IS:2386 - PART IV-1963) and LAAV (ASTM c 131) tests were carried out in order to evaluate the physical properties of aggregates [4 and 9].

2.4.2 Mineralogical properties

Silica content using digestion with HF acid (ASTM C1567 – 13), Iron content using colorimetric spectrophotometry (ASTM D1691 – 12) and the other major metallic elements (Al, Mg, Na, K, Mn & Cr_ASTM D4004 - 06) using atomic absorption spectrophotometry were determined.

2.4.3 Asphalt tests

Under asphalt tests, Marshall Method was conducted in order to determine the bulk density, stability and flow values of Marshall Asphalt specimens[3, 5, 6, 7, 8 and 9]. The Mix Design used for preparing asphalt concrete specimens is presented in Table 2.

Table 2: Mix specification for wearing course [Source: Research & Development Division, RDA, Sri Lanka Rehabilitation & Improvements to Colombo - Kandy road from Kadawatha - Nittambuwa (23 km)]

Sieve size (mm)	% Passing	% Retaining	Retained Wt. (g)
25	100	0	0
19	99	1	12
9.5	74	25	300
4.75	50	24	288
2.36	38	12	144
1.18	30	8	96
0.6	24	6	72
0.3	17	7	84
0.15	10	7	84
0.075	4	6	72
Filler	0	4	48
Total	-	-	1200
Optimum bitumen content by wt. of mix (%)		4.7	

3. Results and Discussion

3.1 Results

Results obtained from the physical tests have been tabulated in Table 3.

Table 3: Summary of physical test results

Sampling Location ID	Bulk Sp. Gravity	UCS (MPa)	AIV%	LAAV%
A	2.75	-	16.157	38.76
B	2.8	-	13.868	34.57
C	2.93	82.962	16.33	38.72
D	2.76	38.206	24.011	47.9
E	2.76	102.61	13.616	26.5
F	2.93	27.29	26.845	60.45
G	2.69	76.412	22.694	32.01
H	2.75	30.565	28.025	60.87

Results obtained from the chemical tests have been tabulated in Tables 4 & 5.

Table 4: Percentage silica contents of respective samples

Sampling Location ID	SiO_2 %
A	30.49
B	20.92
C	22.38
D	5.56
E	22.2
F	16.78
G	29.68
H	15.99

Table 5 – Summary of major metallic element contents

Sam-pling Locat-ion ID	Fe %	Al %	Mg %	Na %	K %	Mn %	Cr %
A	6.08	4.20	0.19	0.23	1.22	0.05	0.02
B	3.96	2.95	0.11	0.25	1.03	0.04	0.02
C	5.55	2.83	0.04	0.23	1.49	0.06	0.02
D	10.37	5.90	0.02	0.47	2.64	0.11	0.01
E	6.05	3.63	0.07	0.19	0.85	0.05	0.03
F	5.11	4.95	0.15	0.25	1.57	0.04	0.03
G	6.18	5.70	0.02	0.28	2.37	0.01	0.03
H	2.49	1.91	0	0.13	0.67	0	0.04

Results obtained from the asphalt tests have been tabulated in Table 6.

Table 6– Summary of asphalt test

Sampling Location ID	Avg. bulk density (g/cm^3)	Avg. stability (kN)	Avg. Flow value (mm)
A	2.486	24.8	11.2
B	2.461	20.66	9.6
C	2.534	19.72	12.4
D	2.532	22.59	11.6
E	2.467	20.67	8.4
F	2.469	21.73	11
G	2.408	24.52	8.8
H	2.468	26.17	10

3.2 Discussion

Figure 2 shows AIV(%), LAAV(%) vs. percentage silica content.

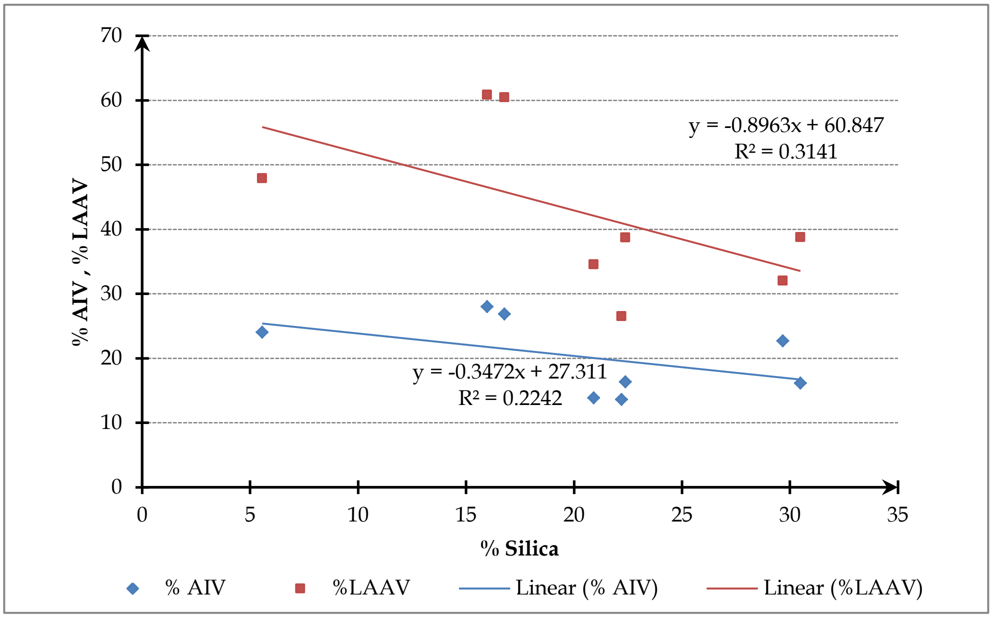

Figure 2 : AIV(%), LAAV(%) vs. percentage silica content

According to statistical regression analysis, respective AIV and LAAV values have decreased significantly with increase of silica percentage. This indicates that, high silica contents will be an added advantage to occupy relatively high resistance over impact and abrasion of the ultimate asphalt pavements.

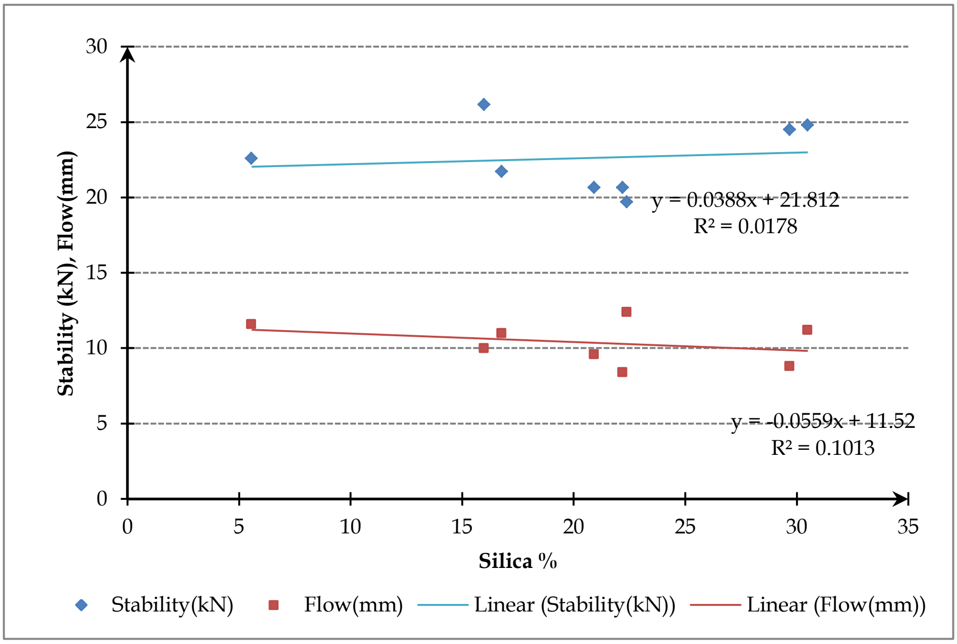

Figure 3 : Stability (kN), Flow(mm) vs. percentage silica content

Figure 3 shows that high silica content results in relatively higher stability and low flow values. This indicates the presence of a high silica content in the constituent aggregates will reduce the strength and lower flexibility of asphalt pavements.

4. Conclusions

- Percentage content of silica in rock aggregates has a significant effect on AIV, LAAV values. Relatively high silica contents results in low AIV and LAAV values, and vice versa.
- Aggregates consisting high silica content, show higher stability values in the ultimate mixture of aggregate and bitumen, resulting in high rigidity in asphalt concrete.
- Aggregates consisting of high silica content, show relatively low flow valus and thus relatively a low flexibility can be experienced in the resulting asphalt concrete.
- Stability shows higher values due to the increased content of silica in constituent aggregates. Brittle fracture can often be experienced in asphalt concrete pavements when subjected to heavy sudden loads. This will also reduce the durability of asphalt pavements.

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